MUSEUM VICTORIA 18 SEP 2012

Distribution of *Westralunio carteri* Iredale 1934 (Bivalvia: Unionoida: Hyriidae) on the south coast of southwestern Australia, including new records of the species

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Westralunio carteri Iredale 1934 is the only hyriid in southwestern Australia. The species was listed as 'Vulnerable' by the IUCN, due to population decline from dryland salinity, although the listing was recently changed to 'Least Concern'. The Department of Environment and Conservation lists the species as 'Priority 4', yet it lacks special protection under federal or state legislation. Accuracy in species accounts is an important driver in determining conservation status of threatened species. In this regard, discrepancies in locality names and vagary in museum records necessitated the eastern distributional bounds of *W. carteri* to be clarified. Here we present an updated account of the species' distribution and describe two previously unknown populations of *W. carteri* in the Moates Lake catchment and Waychinicup River, resulting in an eastern range extension of 96–118 km from the Kent River, formerly the easternmost river where *W. carteri* was known. For mussel identification, samples (n = 31) were collected and transported live to the laboratory for examination and internal shell morphology confirmed that the species was *W. carteri*. Due to an acute salinity tolerance of 3.06 g/L (LD_{50}), the species is unlikely to exist in catchments east of the Waychinicup River where salinities are known to be as high as 45 g/L. The current study clarifies the eastern distribution of *W. carteri* and will allow monitoring of its range decline to be made in the future.

KEYWORDS: freshwater mussel, geographic distribution, Moates Lake, species conservation, Waychinicup River, *Westralunio carteri*

INTRODUCTION

Freshwater mussels (Bivalvia: Unioniformes) are found in freshwater environments on every continent except Antarctica (Bogan & Roe 2008). The life history of these bivalves is generally characterised by their parasitic larvae that usually require fish as hosts (Bauer & Wächtler 2001; Strayer 2008). Parasitic larvae of the Unionoidea (Hyriidae, Margaritiferidae and Unionidae) are known as 'glochidia', which are morphologically distinct from the 'lasidia' or 'haustoria' of Etherioidea (Etheriidae, Iridinidae and Mycetopodidae) (Bauer & Wächtler 2001), although Graf & Cummings (2006) placed the glochidia of the Hyriidae in the Etherioidea based on phylogenetic evidence.

The Southern Hemisphere is dominated by the Hyriidae with 76–83 species occurring in Australasia and South America (Walker *et al.* 2001; Graf & Cummings 2006; Bogan & Roe 2008). Australia currently has 18 nominal species (McMichael & Hiscock 1958; Ponder & Bayer 2004; Walker 2004), although recent genetic investigations have confirmed the existence of additional species, which have not yet been described (Baker *et al.* 2003, 2004; Hughes *et al.* 2004).

The high concentration of endemic flora and fauna unique to southwestern Australia contributes to its listing as one of the world's biodiversity hotspots (Myers *et al.* 2000). The region is comprised of 19 drainage basins with a highly seasonal rainfall and climate pattern similar to that of the Mediterranean, with hot dry summers and cool wet winters (Pen 1999). Many of the formerly freshwater streams, rivers, lakes and wetlands have become affected by dryland salinity through a legacy of land clearing dating back to the late 1800s (Wood 1924; Beresford *et al.* 2001).

Westralunio carteri Iredale, 1934 is the only unioniform to inhabit the South West Coast Drainage Division of Australia (McMichael & Hiscock 1958; Walker 2004). Kendrick (1976) first noted the disappearance of *W. carteri* from the Avon River, and proposed that this resulted from secondary salinisation of its formerly freshwater habitat. Later, results of a biodiversity study (Pinder *et al.* 2004) suggested that *W. carteri* had disappeared from parts of its range within the agricultural zone, strengthening Kendrick's (1976) assessment which resulted in the species being listed as 'Vulnerable' on the International Union for the Conservation of Nature's Red List of Threatened Species (IUCN 1996 *in* Köhler 2011), but was not listed under state or federal legislation. However, the species has recently been assessed as 'Least Concern' '...as it is widespread in Western Australia, is a habitat generalist, and is resistant to organic pollution. Although previously assessed as Vulnerable (under version 2.3 of the Red List) under the revised Categories and Criteria this species no longer qualifies for a threatened listing.' (Köhler 2011). *Westralunio carteri* has recently been shown to have an acute salinity LD_{50} of 3.06 g/L (Klunzinger *et al.* 2010).

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Stewart (2009) proposed two aquatic bioregions for the South Coast Region of Western Australia based largely on salinity and differences in macroinvertebrate compositions, presumably with different salinity tolerance thresholds. In the list of individual species used for the assessment, '*Westralunio* spp.' was reportedly found in greater abundance in the Eastern South Coast where salinities are much higher than in the Western South Coast. Inland freshwater lakes of the south coast were also surveyed for macroinvertebrates by Edward *et al.* (1994), but no *W. carteri* was reported in the study area from Kent River to Esperance.

Records from the Western Australian Museum, Perth (WAM) and the Australian Museum, Sydney (AMS) for *W. carteri* on the south coast east of the Kent River are sparse and locality descriptions are vague, but include the following: AMS_126151, King George Sound (*ca* 1877); WAM_34290, South Stirlings, Calvin River (*ca* 1963); WAM_34289, Esperance Town Beach (*ca* 1978), but no coordinates for these localities are available. In the context of accurate assessment of species conservation, here we present updated and new records for *W. carteri* on the south coast of Western Australia.

MATERIALS AND METHODS

The south coast of Western Australia has been heavily cleared since the 1950s and the land is used primarily for dryland cropping with some plantation forestry and some national parks and nature reserves (Mayer *et al.* 2005). We surveyed regional water bodies for *W. carteri* by tactile searches in wadeable areas of river and lake habitats from 76 sites on the south coast from the Kent River to the Pallinup River during March 2011 and January 2012 (Figure 1). Where mussels were found, patch densities were determined by counting the number of mussels in localised quadrats (1 m^2).

Benthic habitat characteristics, including the dominant substrate type and presence/absence of plant debris were also noted. Specimens were randomly collected from three sites (n = 32) and transported live to the laboratory in a 15 L plastic bucket of river water. Shells were measured as per McMichael & Hiscock (1958) and Walker (2004), subsequently euthanased in 0.01% benzocaine solution, and dissected to determine sex and reproductive status. Gills were examined for the presence (females) or absence (males) of specialised brooding

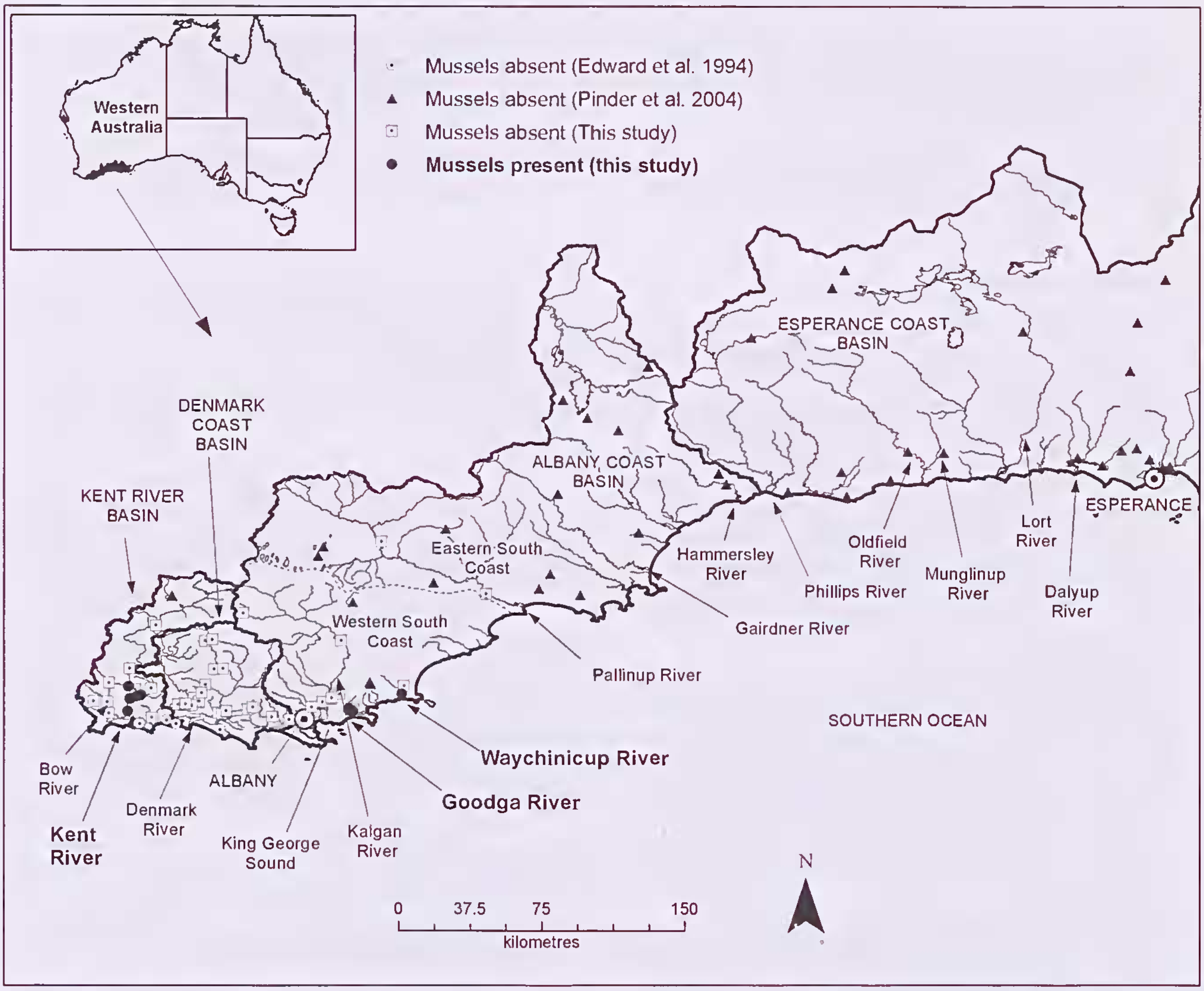

Figure 1 Distribution of *Westralunio carteri* Iredale 1934 in the south coast region of southwestern Australia. Thick black lines represent river basin boundaries and the dashed line represents the boundary between the eastern and western south coast bioregions as proposed by Stewart (2009).

chambers within the demibranchs of the gills ('marsupia') and whether they contained glochidia by the presence or absence of thickened, orange to red coloured marsupia as described for other hyriids (Jones *et al.* 1986; Byrne 1998). Internal shell morphology was examined using McMichael & Hiscock (1958) as a guide. Shells and soft tissues were then preserved in 100% ethanol for future study.

Species distributions from Edward *et al.* (1994), Pinder *et al.* (2004) and this study were mapped using ArcGIS™ Desktop 10. Linear hydrography and river basin boundary data were obtained under license from the Western Australian Department of Water. Coastal and administrative boundaries as well as population centres were mapped from the 'Global Map Australia 1M 2001' dataset (Geoscience Australia 2004).

RESULTS

Freshwater mussels were found in the lower Kent River and new populations were discovered in the Moates Lake catchment in Two Peoples Bay Nature Reserve, located ~30 km east of Albany and in the Waychinicup River, ~22 km east of Moates Lake on the south coast of Western Australia, but no mussels were found in any of the other waterways sampled (Figure 1). All freshwater mussels were identified as *W. carteri*. Marsupia were present in the inner demibranchs of females, a characteristic feature of the Hyriidae. None of the females examined contained glochidia.

Westralunio carteri was found to occupy a 2.4 km stretch of Goodga River, but was not recorded above the fishway at gauging station AWRC 602199 (Figure 2). In Moates Lake, the species was only found within a 300 m^2 area extending beyond the mouth of the Goodga River, but no live mussels were found beyond the river mouth (Figure 2). Densities of *W. carteri* ranged from 1 to 15/m^2, with patch density rapidly decreasing beyond the mouth of the Goodga River (Figure 2). The greatest densities of mussels were found in slower flowing areas around river bends near the banks, nestled amongst submerged tree roots. Where mussels were found, the substrate was dominated by coarse sand with some woody debris and leaf litter. Above the Goodga River gauging station, benthic habitats consisted primarily of soft sludge and detritus.

Very few mussels were found in the small area of Waychinicup River, but four individuals were located near a submerged log in fine sand and silt. All of the sites that contained *W. carteri* had characteristic tannin-stained water and were fringed by well-vegetated river banks lined with thick shrubs, and shading trees.

DISCUSSION

To our knowledge, this study represents the first account of *W. carteri* from the Moates Lake catchment and Waychinicup River of the south coast, which together are probably the only remaining populations within the Albany Coast Basin, although neighbouring streams such as the Angove River may also support the species. We suspect that the current existence of *W. carteri* on Esperance Town Beach (WAM_34289, *ca* 1978) is unlikely given that mean salinities of rivers near Esperance are greater than 5 g/L, and have been since the late 1970s (Mayer *et al.* 2005). *Westralunio carteri* was recorded from the King George Sound locality in the late 1800s, but the exact location is not available from Australian Museum records. Although a record for the species exists in the 'Calvin River', there is no river by that name in Western Australia and was probably made in error. The record probably refers to the Kalgan River, but this has not been confirmed. If indeed the species did exist in this locality, the new information from this study possibly represents

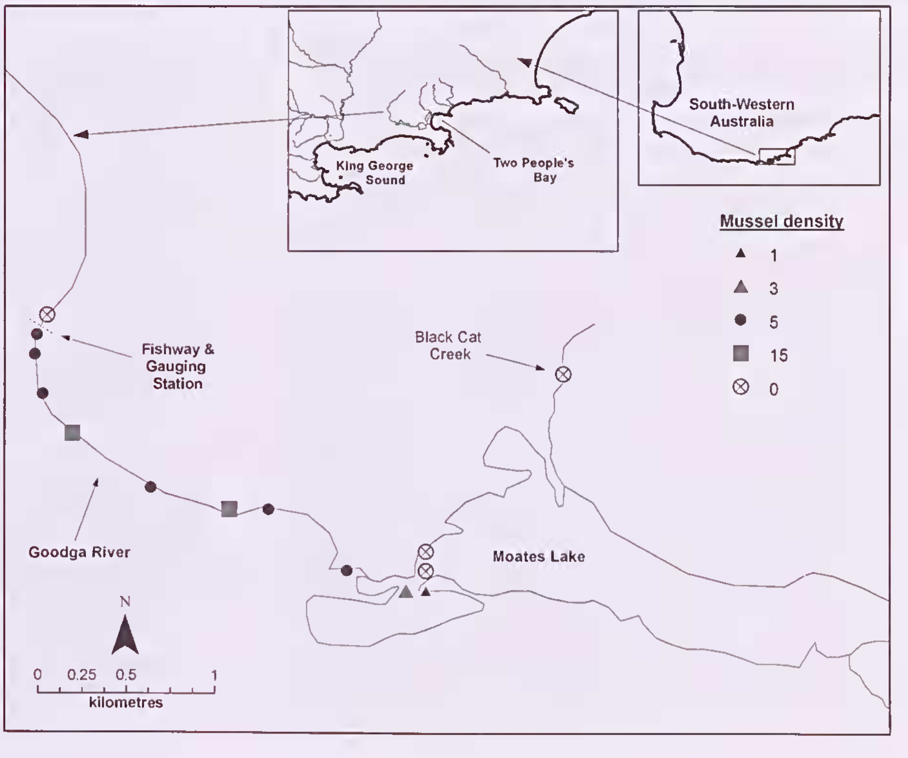

Figure 2 Distribution of *Westralunio carteri* Iredale 1934 in the Moates Lake catchment of southwestern Australia. Mussel density symbols represent the number of mussels per 1m^2 quadrat.

a range extension of ~8–30km east from Kalgan River. However, our recent surveys failed to record the species in the Kalgan River, thereby placing the nearest population 96–118 km to the west in the Kent River.

Waychinicup River represents the easternmost limit of the distribution of endemic freshwater fishes (Morgan *et al.* 1998, 2011), which is probably true for *W. carteri* as well. Very few, if any perennial rivers east of Waychinicup are fresh (Mayer *et al.* 2005; Stewart 2009), with a majority of the rivers in the region having salinities above the known acute tolerance of 8.2–14.6 g/L for several endemic freshwater fishes (Beatty *et al.* 2011), and 3.06 g/L for *W. carteri* (Klunzinger *et al.* 2010), so the likelihood of finding freshwater mussels in salinised rivers in the Eastern South Coast is probably low. The species data from Pinder *et al.* (2004), presented in Figure 1, lends support to this presumption. Although Stewart (2009) reported '*Westralunio* spp.' occurring in many of the salinised rivers of the south coast, the species identification was probably erroneous and was most likely *Fluviolanatus subtorta* (Dunker 1857), based on photos provided by the former author (B Cook pers. comm. 2010). This trapezoid has migrated inland from estuaries to salinised rivers of the region such as Avon River (Kendrick 1976) and Blackwood River (Pen 1999). We have also observed this species and *Mytilus* (*Mytilus*) *planatus* Lamarck 1819, a marine/estuarine mytilid, inhabiting the salinised Kalgan River nearly 40 km inland from the estuary.

Besides salinity, sedimentation may be causing localised declines based on our observations of the species elsewhere, which is supported by Jones & Byrne (2010) who found that sedimentation is a limiting factor for eastern Australian hyriids. Reservoir dewatering and rainfall reductions appear to be having a negative effect on *W. carteri* populations (M W Klunzinger *et al.* unpubl. data). The region's climate is changing, most notably since the 1970s with rainfall, surface flow and groundwater reductions, amplifying the effect of dryland salinity and increasing the vulnerability of freshwater fishes to population loss with the trend expected to continue into the future (Morrongiello *et al.* 2011).

Due to limited time and resources during the survey, we did not collect an adequate number of mussels to draw any conclusions from shell measurements about population structure. Because growth rates, host fishes and reproductive biology of *W. carteri* in these systems have not been quantified, we are reluctant to infer age, reproductive status or recent recruitment patterns. Future assessments of the population structure in these systems should utilise a more rigorous sampling design to maximise the probability of collecting the full range of size classes and in greater quantity for statistical power.

The absence of *W. carteri* above the gauging station weir in Goodga River could be due to the build-up of detritus and fine sediments which have been known to cause hypoxia/anoxia and a build-up of un-ionised ammonia (NH_3) during summer months and non-flow or slow-flow periods which is particularly lethal to juvenile freshwater mussels elsewhere (Bauer & Wächtler 2001; Strayer 2008). Prior to the fishway being opened in April 2003, upstream migration of fishes was prevented by the gauging station weir and no fish of any species existed above the weir before the fishway was opened (Morgan 2003; Morgan & Beatty 2006). If host fishes could not deliver attached glochidia upstream of the gauging station and if aging mussels above the weir were unable to expose their glochidia to potential hosts, they could have died out from recruitment failure. If we knew the longevity of adult *W. carteri* in this system, had information on suitable host fishes, knew tolerance thresholds for NH_3 and whether we could find juvenile *W. carteri*, we would be able to test these hypotheses. Although host fishes in these systems are unknown, *Nannoperca vittata* (Castelnau 1873) and *Pseudogobius olorum* (Sauvage 1880) which are known to inhabit both Goodga and Waychinicup Rivers (Morgan & Beatty 2006; Morgan *et al.* 1998, 2011) are likely candidates given that they are known to support glochidia of *W. carteri* elsewhere in its range (Klunzinger *et al.* in press). The Goodga River contains Australia's only Critically Endangered fish, *Galaxias truttaceus* (Cuvier & Valenciennes 1846) as well as *Galaxias maculatus* (Jenyns 1842) (Morgan 2003; Stewart 2011; Morgan & Beatty 2006; Morgan *et al.* 1998, 2006, 2011), both of which may be hosts for glochidia.

The accuracy of species distributions is important for conservation assessments, particularly at the broad regional scale (Anderson & Martínez-Meyer 2004). This study adds to the current state of knowledge on the biogeography of *W. carteri*, namely extent of occurrence, which is a key criteria used for conservation assessment under the Western Australian Wildlife Conservation Act 1950, the federal Environment Protection and Biodiversity Conservation Act 1999 and the IUCN Red List of Threatened Species. Results from this study will undoubtedly be useful in future conservation assessments of the status of the species. Factors influencing the occurrence of this species in relation to conservation criteria should be the focus of ongoing investigations.

ACKNOWLEDGEMENTS

This work was funded by a grant from the Holsworth Wildlife Research Endowment and an International PhD Scholarship from Murdoch University. A License to Take Fauna for Scientific Purposes (Regulation 17 of the Wildlife Conservation Act 1950) was obtained from the Department of Environment and Conservation and a Research Permit (under exemption from the Fish Resources Management Act 1994) from the Department of Fisheries. We especially thank James Keleher and Iain Foster for their help during field sampling. We thank two anonymous reviewers for constructive criticism during review of earlier versions of this publication and Pierre Horwitz for helpful comments and suggestions during revision of the manuscript.

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Received 1 November 2011; accepted 3 May 2012